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Utilization of oil palm as a source of renewable energy in Malaysia

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Abstract

Malaysia is currently the world's largest producer and exporter of palm oil. Malaysia produces about 47% of the world's supply of palm oil. Malaysia also accounts the highest percentage of global vegetable oils and fats trade in year 2005. Besides producing oils and fats, at present there is a continuous increasing interest concerning oil palm renewable energy. One of the major attentions is bio-diesel from palm oil. Bio-diesel implementation in Malaysia is important because of environmental protection and energy supply security reasons. This palm oil bio-diesel is biodegradable, non-toxic, and has significantly fewer emissions than petroleum-based diesel (petro-diesel) when burned. In addition to this oil, palm is also a well-known plant for its other sources of renewable energy, for example huge quantities of biomass by-products are developed to produce value added products such as methane gas, bio-plastic, organic acids, bio-compost, ply-wood, activated carbon, and animal feedstock. Even waste effluent; palm oil mill effluent (POME) has been converted to produce energy. Oil palm has created many opportunities and social benefits for the locals. In the above perspective, the objective of the present work is to give a concise and up-to-date picture of the present status of oil palm industry enhancing sustainable and renewable energy. This work also aims to identify the prospects of Malaysian oil palm industry towards utilization of oil palm as a source of renewable energy.

Keywords: Oil palm; Energy; Palm oil; Bio-diesel; Biomass

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Contents

1. Introduction

The oil palms (*Elaeis guineensis*) comprise two species of the *Arecaceae*, or palm family. Mature trees are single-stemmed, and grow up to 20 m tall. The leaves are pinnate, and reach between 3 and 5 m long. The flowers are produced in dense clusters; each individual flower is small, with three sepals and three petals. Unlike, the coconut palm, the oil palm does not produce offshoots; propagation is by sowing the seeds. The fruit takes 5–6 months to mature from pollination to maturity; it comprises an oily, fleshy outer layer (the pericarp), with a single seed (kernel), also rich in oil [1]. Oil palms are commonly used in commercial agriculture in the production of palm oil.

The oil palm is a tropical palm tree therefore it can be cultivated easily in Malaysia. The oil palm tree in Malaysia originated from West Africa where it was growing wild and later developed into an agricultural crop. The first commercial oil palm estate in Malaysia was set up in 1917 at Tennamaran Estate, Selangor [2,3]. Pictures 1–4 show the palm tree and its accessories. The palm tree and palm fruit are shown in Pictures 1 and 2, whereas Pictures 3 and 4 show the oil palm biomass and palm oil mill effluent (POME). The pictures are courtesy of United Oil Palm Sendirian Berhad, Nibong Tebal, Pulau Pinang.

The growth of the industry has been phenomenal and Malaysia is now the largest producer and exporter of palm oil in the world, accounting for 52% or 26.3 million tonnes (MnT) of the total world oils and fats exports in year 2006. With the increasing demand of world vegetable oil for example from 58.8 MnT in year 1991/1992 to 109.2 MnT in year 2005 and to 137.9 MnT in year 2006, Malaysia will be one of the major contributors of world vegetable oil in near future. Fig. 1 shows the types of vegetable oil used throughout the world and their demand in percentage for the year 2005 [4–7]. It shows that palm oil accounts the highest percentage of demand comparatively to other types of oil in the

Picture 1.

Picture 2.

Picture 3.

Picture 4.

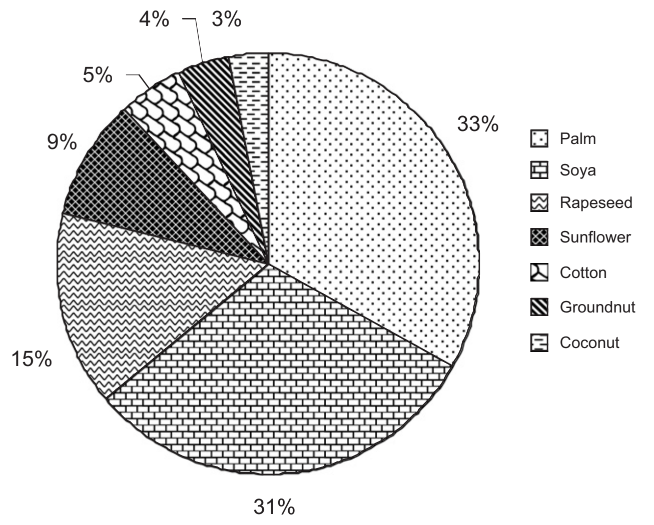

Fig. 1. Vegetable oil demand year 2005 [5].

Table 1
Oil production analysis of oil palm compared to soybean, rapeseed and sunflower in year 2006 [8]

Oil crop	Production (millon tonnes)	% Of total production	Average oil yield (tonnes/ha/year)	Total area (million ha)	% Area
Oil palm	36.90	35.90	3.74	9.86	4.50
Soybean	35.19	34.24	0.38	92.63	42.27
Rapeseed	18.34	17.84	0.67	27.29	12.45
Sunflower	11.09	10.79	0.48	22.95	10.47

world. Table 1 shows the comparative values of world palm oil production to other types of oil for the year 2006 [8].

Oil palm is the highest yielding oil crop, producing on average about 4–5 tonnes of oil/ha/year, about 10 times the yield of soybean oil [9]. Soybean oil was a distant second at 19%. Palm oil demand was significantly increased by 10.6% to 33.17 MnT in year 2006. Both palm and soybean oils combined, govern almost 48% of global oils and fats consumption in year 2006. Palm oil itself contributes about 33% of the world vegetable oil demand [7,10]. In terms of the world market, both Malaysia and Indonesia account for 90% of the palm oil world export trade and will likely remain the key players in the palm oil sector, accounting for 28.5 MnT or 85% of the world's palm oil production. This numbers can be clearly verified in Fig. 2 [10].

It was forecasted that in years to come, the demand will be higher with the increasing demand of world total oils and fats. Table 2 shows the forecasted projected production of palm oil for the year 2000–2020 in MnT [8] for the two major world palm oil contributor.

It is already very profitable to invest in the industry of oil palm in Malaysia even using existing technology; as a result it enhances the plantation of oil palm in Malaysia. Malaysia contributes about 10% of the global oils and fats utilizing only 4 million ha of land, which

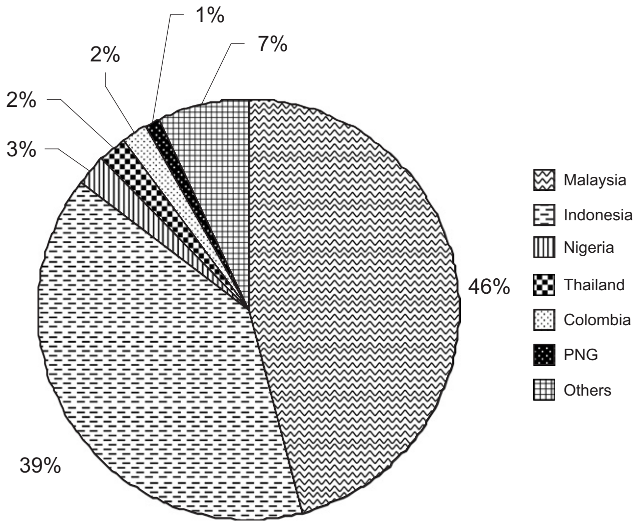

Fig. 2. Palm oil exports to the world consumption year 2005 [10].

Table 2
Present and forecasted production of palm oil for the year 2000–2020 in MnT [8]

Year	Malaysia	Indonesia	World total
Annual production			
2000	10,100 (49.3%)	6700 (32.7%)	20,495
2001	10,700 (48.1%)	7720 (34.7%)	22,253
2002	10,980 (48.4%)	7815 (34.5%)	22,682
2003	11,050 (47.7%)	8000 (34.6%)	23,149
2004	10,900 (45.6%)	8700 (36.4%)	23,901
2005	11,700 (45.6%)	9400 (36.6%)	25,666
Five-year averages			
1996–2000	9022 (50.3%)	5445 (30.4%)	17,932
2001–2005	11,066 (47.0%)	8327 (35.4%)	23,530
2006–2010	12,700 (43.4%)	11,400 (39.0%)	29,210
2011–2015	14,100 (40.2%)	14,800 (42.2%)	35,064
2016–2020	15,400 (37.7%)	18,000 (44.1%)	40,800

corresponds to 1.84% of the world's total 219 million ha of oilseeds [10], can produce a gigantic 11% of the global vegetable oils extensively when compared to its planting area size. Therefore plantation of oil palm tree in Malaysia has been boasted significantly in the recent years and Fig. 3 proves this.

Fig. 3 shows that only about 38,000 ha of land have been used in 1950, whereas 4,050,000 ha have been used in year 2005 for oil palm plantation [11]. The oil palm currently yields an average of 3.7 MnT/ha of oil/year, which is 2.5 times higher than rapeseed and about seven times more than soy. This attests that the utilization of oil palm as a source of energy is certainly increasing. Malaysian oil palm can be used to produce many other downstream oleo-chemical products such as soap, palm fatty acids, palm

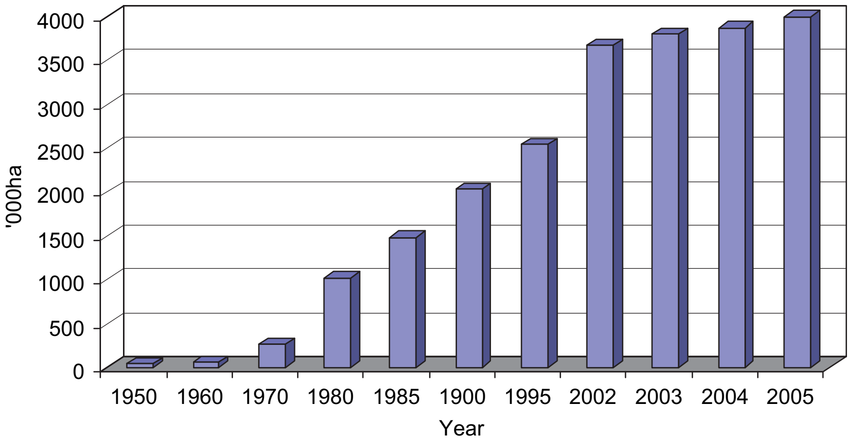

Fig. 3. Oil palm expansion in Malaysia from 1950 to 2005 [3].

methyl esters and many more. Apart from that, huge quantities of biomass by-products such as empty fruit bunch (EFB) fibers, shells, fronds, and trunk are also produced. These biomasses can be converted into many value added product. Hence the objective of this paper will be outlining the contributions of oil palm's by products as well as its oil as a source of renewable and sustainable energy.

2. Palm oil

Palm oil is the second most traded vegetable oil crop in the world after soy and over 90% of the world's palm oil exports are produced from Malaysia and Indonesia, shown in Fig. 2 [10]. Palm oil is derived from the fruit flesh of the oil palm. The palm fruit is about the size of a small plum and grows in large bunches weighing 10–20 kg. A bunch can have up to 2000 individual fruits. Each fruit consists of a hard kernel (seed) inside a shell (endocarp), which is surrounded by a fleshy mesocarp. Oil is extracted from both the pulp of the fruit (palm oil—edible oil) and the kernel (palm kernel oil (PKO), used mainly for soap manufacture. Crude palm oil (CPO) is the primary product derived from the red fruits of the oil palm, while PKO, derived from the fruit's nut is considered to be a secondary product. Hence two types of oils, i.e. CPO and crude palm kernel oil (CPKO) [12] are produced. Although both oils originate from the same fruit, palm oil is chemically and nutritionally different from PKO. Furthermore palm oil is one of the only two mesocarp oils available commercially, the other being olive oil.

Palm oil is semi-solid at room temperature; a characteristic brought about by its approx. 50% saturation level. In its virgin form, the oil is bright orange-red in color due to its high content of carotene. Palm oil contains palmitic acid (a fatty acid made by our body), the monounsaturated oleic acid, polyunsaturated linoleic acid (an essential fatty acid) and stearic acid. The typical blend in palm oil is 45% palmitic, 40% oleic, 10% linoleic and 5% stearic. Palm oil (and its products) has good resistance to oxidation and heat at prolonged elevated temperatures; hence, making palm oil an ideal ingredient in frying oil blends. Manufacturers and end-users around the world incorporate high percentages of palm oil in their frying oil blends for both performance and economic reasons [2]. In fact, in many

instances, palm oil has been used as 100% replacement for traditional hydrogenated seed oils such as soybean oil and canola. Products fried in palm oil include potato chips, fries, doughnuts, ramen noodles and nuts [2]. The palm oil is also rich in natural chemical compounds important for health and nutrition. Among others, it is a natural source of carotenoids and vitamin E as well as supplying fatty acids and other important fat-soluble micronutrients. It also supplies an abundance of calories that gives us much-needed energy for our daily life. CPO is the richest natural source of tocotrienols which is a fat-soluble vitamins related to the family of tocopherols. In recent studies and research there is now a reasonable and ever-growing body of scientific literature documenting the anti-cancer properties of the tocotrienols and palm oil do attest this properties [13]. Lately, the Malaysian Palm Oil Board (MPOB) has developed a special patented technology for extraction. The latest technology to purify tocotrienols from the fruits of oil palm was developed to produce a superior quality and purity [12]. Refined red palm oil is used for the treatment and prevention of vitamin A deficiency. Palm oil is indeed a nature's gift to Malaysia, and Malaysia's to the world.

In terms of energy expression, oil palm is an energy efficient crop that requires less energy input to produce 1 tonne of oil. The energy expressed by the ratio energy output to input is wider for oil palm than any other commercially grown oil crops sources such as soybean and rapeseed. The ratio energy output to input of these crops can be seen in Fig. 4 below. The energy output of oil palm is almost 3 times higher comparatively to soybean and rapeseed oil. Moreover oil palm cultivation and processing requires lower inputs of agrochemicals (pesticides), fertilizers and fossil fuels to produce 1 tonne of oil, with fewer resulting pollutions and emissions [11].

The total production of palm oil in Malaysia for the year 2006 is clearly shown in Table 3. The table shows that more than 89% of the palm oil produced in Malaysia was

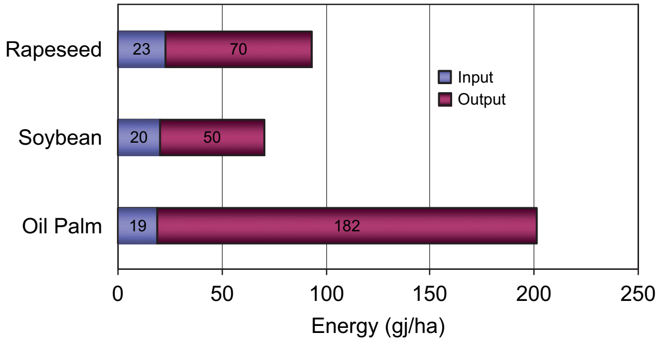

Fig. 4. Input and output energy consumption of crops [11].

Table 3
Total production and export of palm oil year 2006 [4,14]

Year 2006 market share	Production (MnT)	Export/trade (MnT)
Malaysian palm oil	14.96	13.44
World palm oil	33.5	26.5
World oils and fats	139.81	50.91

exported or traded. This amount is about 40% of the world palm oil production. These numbers show high impact on the production of renewable energy by utilizing local oil palm.

3. Palm oil bio-diesel

There is a continuously increasing interest concerning the bio-fuel implementation in Europe and other countries, mainly because of environmental protection and energy supply security reasons. Future shortage in petroleum supply and surging prices for petroleum-based fuels, coupled with the increasing awareness of green house gas emissions increase the shift towards the alternative fuels sector. An alternative fuel must be technically feasible, economically competitive, environmentally acceptable and readily available. One possible alternative to petroleum-based fuels is the use of oils of plant origin like vegetable oils and tree borne oil seeds. Hence this crop oil can be used as renewable resource for fuel energy. This alternative fuel is termed as bio-diesel.

Bio-diesel is chemically defined as a methyl ester, which can be prepared from triglycerides in vegetable oils by transesterification with methanol [15]. This fuel is biodegradable, renewable, clean, non-toxic, and has low emission profile as compared to petroleum diesel.

Bio-diesel is mainly produced from vegetable oils, which are derived from the seeds or the pulp of oil-bearing crops. There are two types of oil crops. It can be annual (rapeseed, groundnut, soybean, and sunflower) or perennials (coconut palms, oil palms, physical nut, and Chinese tallow tree). Oil from the rapeseed was the first type used for bio-diesel production and in Europe rapeseed is still the main feedstock for bio-diesel production [16]. Among the sources, palm oil is the cheapest vegetable oil and has the highest oil yields/ha of plantation.

In Malaysia, palm diesel has been established as diesel substitute since 1996 [9], whereby CPO, crude palm stearin, and CPKO can be readily converted to their methyl esters [17]. Currently Malaysia is pilot-testing B5, a blend of 5% refined olein and 95% diesel in vehicles. The final output of this pilot testing was launched by the Prime Minister Datuk Seri Abdullah Ahmad Badawi on Tuesday 22 March 2006 as Envodiesel [18]. Envodiesel branded bio-diesel blends 5% processed palm oil (vegetable oil) with 95% petrodiesel [18]. In contrast, European Union's B5 blends 5% methyl ester with 95% petrodiesel. Diesel engine manufacturers prefer the use of palm oil methyl ester blends because diesel engines are designed to handle 5% methyl esters meeting the EN14214 bio-diesel standard. Malaysia researches are now keen on producing palm oil methyl ester to satisfy the EU's blends and standards. Blending 5% processed palm oil with any type of diesel available in the country will create a new demand for 260,000 tones of palm oil (assuming national production of 5.2 MnT of diesel/year). In this case, an increase of RM 100 in palm oil price will lead to a gain of revenue of RM 520 million (assuming the export of 5.2 MnT/year) for the country [19].

Malaysia presently produces 500,000 tonnes of bio-fuel annually and the government hopes to increase this number in years to come. Therefore, palm bio-diesel is considered the most possible substitute of conventional diesel fuel. Recently, high petroleum prices have stimulated the rapid expansion of the bio-diesel industry. In liter terms, the imported price of petroleum diesel is RM 2.10 against RM 1.40 for palm oil. On top, with crude oil prices reaching a new high of USD 78.18/barrel in mid-July 2006 on the New York

Mercantile Exchange and palm oil prices at RM 1700/tonne November, 2006, it has become profitable to use palm oil for bio-diesel [20]. Other than this, developing bio-diesel industry in Malaysia is expected to contribute greatly to the development of the country. The following are the advantages of introducing bio-diesel industry in Malaysia and these advantages have been outlined in the National Biofuel Policy [19]:

a. mitigating the effects of petroleum price escalation,
b. savings in foreign exchange by reducing the imports of petroleum diesel,
c. environment friendly source of energy by reducing the emissions of greenhouse gases,
d. creating new demand for palm oil,
e. mutually beneficial effects on petroleum and palm oil sectors,
f. achieving socio-economic safety net, and
g. efficient utilization of raw materials.

With the current global trend towards renewable fuels, Malaysia has the edge over other nations as the pioneer palm bio-diesel producer. In this aspect, Malaysia has decided to set aside 6 MnT/year of the commodity as feedstock for production of bio-fuels and bio-diesel, nearly 40% of its CPO production [21,22]. To date, 52 manufacturing licenses have been approved [23], reflecting a great deal of interest in the investment of bio-diesel. As predicted in year 2007, Malaysia would be able to produce 300,000 tones of bio-diesel, out of 5.2 MnT, which has been approved by the government [22].

4. Oil palm biomass

As discussed earlier, Malaysia's position as the world's leading palm oil-producing country has allowed the industry to flourish in the way it has never been before. Hence currently researches are churning out a wider variety of by-products as a result of continuous R&D efforts; making the downstream manufacturing into an industry itself. Whereby abundant waste biomasses are turned into renewable energy or value added products. This allows Malaysia to remain heads and shoulders above its other competitors. Fig. 5 shows the scope of biomass initiatives.

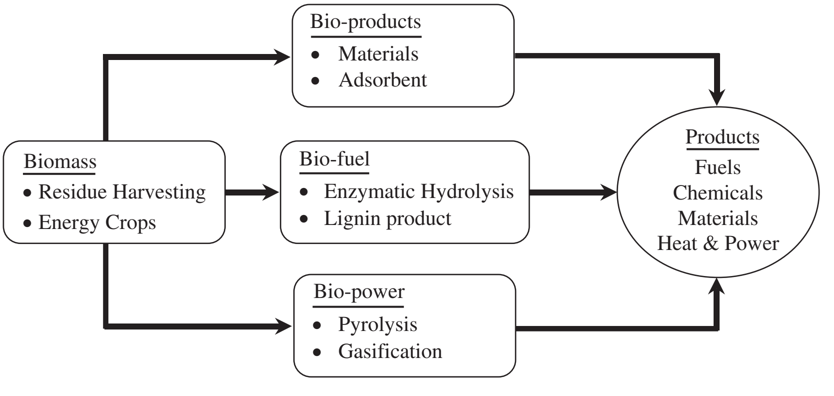

Fig. 5. Biomass initiatives as renewable energy.

Table 4
Types of renewable energy in Malaysia and its energy value [25]

Renewable energy source	Energy value in RM million (annual)
Forest residues	11,984
Oil palm biomass	6379
Solar thermal	3023
Mill residues	836
Hydro	506
Solar PV	378
Municipal waste	190
Rice husk	77
Landfill gas	4

Table 5
Types of biomass and quantity produced [12]

No.	Type of biomass	Quantity/annum (MnT)
1.	Empty fruit bunch (EFB)	15.8
2.	Fronds	12.9
3.	Mesocarp fiber (MF)	9.6
4.	Trunk	8.2
5.	Shell	4.7

Biomass, in the energy production industry, refers to living and recently living biological material, which can be used as fuel or for industrial production. Biomass conversion systems are arrangements, which can be large and produce electricity (bio-power) and heat; or small—a wood stove or small wood-fired furnace using biomasses. Biomass conversion can also produce bio-fuels, which include ethanol, methanol, bio-oil, and bio-diesel. Biomass energy or bio-energy is the largest source of domestic renewable energy. Many Malaysian industries such as sugar, palm oil, rice, and wood have been utilizing their biomass as a fuel to cover some or all of their energy requirements [24]. Table 4 shows the study that identifies the renewable energy resource potential in the Malaysia, in Ringgit value. Based on the data above, oil palm biomass has been identified as one of the biggest resource that can be easily developed. Whereby, oil palm biomass contributes about RM 6379 million of energy annually [25]. Despite its wide use already, there is still much to be done to optimize the utilization of biomass for cogeneration in Malaysia.

Oil palm mills generally generate numbers of biomass wastes. The amount of biomass produced by an oil palm tree, inclusive of the oil and lignocellulosic materials is on the average of 231.5 kg dry weight/year [26]. Table 5 shows types of biomass produced from oil palm tree and the quantities produced per annum in MnT. These biomasses have high potential of turning into renewable energy. Empty fruit EFB and mesocarp fiber (MF) is the highest contributor of oil palm biomass, whereby about 15.8 and 9.6 MnT, respectively have been produced/year [12].

Oil palm fronds are available daily throughout the year when the palms are pruned during the harvesting of fresh fruit bunch for the production of oil. Oil palm trunk is obtained during the re-plantation of the oil palm trees. EFB, MF and shells are collected

during the pressing of sterilized fruits [17]. Oil palm biomasses can be transformed into three types of biomass energies: i.e. bio-products, bio-fuels, and bio-power.

4.1. Bio-products

Palm oil biomasses can be utilized to produce various types value added products. Whereby oil palm biomasses such as the EFB and MF have been modified and processed to produce molded oil palm (MOP) products. MOP product is a unique bio-based material made from oil palm particles and thermoset resin in matched metal disc under heat and pressure. MOP products are extremely versatile and can be used in furniture, building, electronics, packaging, and automobile industries [27]. One of the latest researches by the MPOB onto EFB is to convert EFB into paper-making pulp. The pulp is then bleached using the total chlorine-free (TCF) methods to obtain sheets of paper [17,27]. Pulp and paper used from oil palm biomass can be used in many ways such as cigarette paper and bond papers for writing [28]. Hence with this advancement from using oil palm biomass, Malaysia need not import pulp from other nations. Presently, most of the EFB and MF are used as soil conditioners in estates and plantations [29] and incinerated to obtain oil palm ash (OPA) that can be used as a source of fertilizer due to its high potassium content [26]. Some researches have utilized this OPA to synthesize absorbents for toxic gas removal (sulfur dioxide, SO_x). The active compound (silica, alumina, potassium, calcium, and hydrated water) in the absorbent prepared from OPA is believed to be responsible for the high absorption capacity of SO_x [30–32]. EFB and MF also have been used to manufacture medium density fibre-board (MDF) and blackboard [26,33]. The latest research and output of the local scientists proved that the palm kernels, EFB, palm shells, and stones can be converted into value added products such as oil palm activated carbon [34–36]. This oil palm activated carbon has been used to treat air toxics such as carbon monoxide (CO) and SO_x [37,38].

Most of the oil palm trunk is converted into various types of wood such as saw-wood and ply-wood or lumber. Oil palm lumber has been successfully utilized as core in the production of blackboard. The saw-wood produced from oil palm can be used to make furniture but not for building structure due to its low specific density. However, the strength of the ply-wood produced from oil palm was found to be comparable with commercial ply-wood. The excess shells are usually used to cover the surface of the roads in the plantation area. Oil palm trunk also has been used to produce particleboards with chemical binders. Moreover, some of the trunks are mixed with EFB and oil palm fibers to be combusted and produce energy [17,26].

Fronds are a source of food for ruminants (cattle and goats). Fronds are also left to rot in between the rows of oil palm trees in the plantation for following reasons: (a) soil conservation; (b) increase the fertility of the soil; (c) increase the amount of water retain in the soil; (d) erosion control; and (e) provide a source of nutrient to the growing oil palm tress (Nutrient is recycled, as a long term benefits) [26].

Besides this, oil palm kernel cake (PKC) has been used to produce animal feed [39,40]. Some of the waste fatty acids from the kernel and CPO have been used to make fatty acid-based product for animal feed, calcium soap and palm fatty acid distillate (PFAD) [39]. In addition to this the oil-production process yields copious amounts of residues that find use in biogas production, as a bio-energy feedstock for co-firing with coal or as base chemicals for the production of bio-plastics and a series of highly valuable biomaterials.

4.2. Bio-fuels

Oil palm biomass can be used to make the same products that are created by fossil fuels, sometimes using less energy to do so. Synthetic biofuels are synthetic hydrocarbons or mixtures of synthetic hydrocarbons from biomass, e.g. SynGas (SNG) produced from gasification of forestry biomass or SynDiesel. There are 3 types of bio-fuels that is: bio-ethanol, bio-diesel, and bio-methanol. Bio-ethanol fuels are mainly produced by fermentation from grains rich in sugar or starch. Oil palm waste fibers especially EFB are rich in sugar. Research papers show that EFB have been used to produce glucose and xylose successfully [41,42]. EFB can be used as a feedstock for second generation ethanol to produce bio-oil and bio-ethanol through pyrolysis and fermentation or hydrolysis, respectively. Flexible-fuel vehicles can run on about 85% ethanol made from these biomasses [43,44]. Bio-methanol is methanol produced from biomass. A new study patented in Swedish technology concluded that the alcohol fuel methanol can be produced from biomass via black liquor gasification at a cost competitive with that of gasoline and diesel [45]. One of the recent studies on oil palm biomass waste showed that black liquor can be produced from the trunk of oil palm but at present the black liquor is used to produce pulp and paper [46,47]. With this up-coming research, one day it is predicted that EFB and the waste trunks of oil palm can be used to produce bio-methanol.

4.3. Bio-power

Bio-power is the use of biomass to generate electricity. Types of bio-power systems include direct-fired, gasification, anaerobic digestion, pyrolysis, and small, modular systems. Direct-fired systems consist of burning bioenergy feedstocks to produce steam, which is then captured by turbines that spin a generator, eventually creating electricity. EFB and MF are normally used for this process in the existing oil palm factories whereby heat energy is produced through burning or direct combustion [26] and then captured to spin an electric generator. Ligno–cellulosic biomass, i.e. the EFB, can be converted to hydrogen gas through gasification process. On the other hand, the MF and shell contain a small quantity of oil, hence they are used as boiler fuel to generate steam for mill consumption [9]. Most palm oil mills burn all of their fiber and some shells as boiler fuel to produce steam for CPO extraction and a small amount of electricity for internal use [29].

Recently Chubu Electric Power has announced plans to build two biomass power plants in the eastern province of Sabah, Malaysia. This new biomass plants will use the leftover-disposable palm bunches as renewable energy source to generate the output of a 10,000 kW small-scale electric power plant. The palm biomass power plant will also fulfill CO_2 emission trading standards, guidelines set up by EU in 2002 for a trading system for greenhouse gas emission allowances. Chubu aims to reduce CO_2 by 2 MnT annually with the new plant, and acquire the CO_2 emission trading credits [48].

Another proposed Project in Malaysia is a biomass power plant with 11.5 MW capacity, which will generate and supply electricity to the fossil fuel intensive Peninsular Malaysia grid. It is fuelled by a renewable source and supplies electricity to a distributor that is supplied by at least one fossil fuel generating unit. In this project EFB will be combusted in a boiler to produce electricity. This project is currently in the progress of building the power plant in Pantai Remis, Perak by Bumibiopower Sdn. Bhd [29].

5. Palm oil mill effluent

The major source of wastewater generation from palm oil mill is namely sterilizer condensate, hydrocyclone waste, and separator sludge. On an average 0.9–1.5 m^3 of POME is generated for each ton of CPO produced. The POME is rich in organic carbon with a biochemical oxygen demand (BOD) value higher than 20 g/L and nitrogen content around 0.2 and 0.5 g/L as ammonia nitrogen and total nitrogen [17,49]. Table 6 shows the complete characteristics of a typical POME. Currently POME is converted into fertilizers and used in the nearby farm and vegetation area [50]. This data show that POME can be used to produce bio-gas through anaerobic treating system. Anaerobic digestion describes the process by which bacteria in organic matter decompose without the use of oxygen; the result is extractable methane that is used as a source of energy. Therefore the processing of 20 tonnes of fresh fruit bunches, releases 100 tonnes of POME, that yield about 400 m^3 of biogas. [17,43,44]. As the reserves of oil and gas are being depleted, security of energy supply has raised the demand towards the establishment of hydrogen economy. Hence, Malaysian researches have studied the effect of hydrogen production from POME using microflora isolated form the sludge of an anaerobic pond treating POME [51,52]. It was a successful procedure and the average biogas generation was found to be 0.42 L/g COD destroyed, with a hydrogen content of $57 \pm 2\%$ at 7 d HRT. The generated biogas was free from methane [51,52].

Currently, a company 'Bumibiopower' is a renewable energy power plant developer in Malaysia by Mitsubishi Securities Co., Ltd. a Japanese company. This company is in the progress of setting up a plant for methane extraction and power generation using POME near Pantai Remis. The project activity is to install a closed anaerobic system that will produce and collect consistently high quality of methane-rich biogas from POME. This project also includes the installation of a generator, which will be fed by the collected biogas to produce renewable electricity. The size of the generator is expected to be between 1 and 1.5 MW [54].

6. Oxygenating air

Oil palm plantations account about 3.67 million ha of the total area under selected crops in the country (55). Such a large green vegetation cover makes an effective 'carbon

Table 6
Characteristics of palm oil mill effluent [53]

Parameter	Concentration (mg/L)	Element	Concentration (mg/L)
Oil and grease	4000–6000	Potassium	2,270
Biochemical oxygen demand	25,000	Magnesium	615
Chemical oxygen demand	50,000	Calcium	439
Total solid	40,500	Phosphorus	180
Suspended solids	18,000	Iron	46.5
Total volatile solids	34,000	Boron	7.6
Total Nitrogen	750	Zinc	2.3
Ammonicals nitrogen	35	Manganese	2.0
		Copper	0.89

sink'—areas of dry matter that absorbs harmful greenhouse gas. In this case large oil palm vegetation acts as a sequester of carbon dioxide (CO_2). Under the Kyoto Protocol, the carbon sink of oil palm can be converted to carbon credit, which is a promising trade (56). Moreover, the oil palm forest also assimilates 44 tonnes of dry matter/ha/year compared to 25.7 tonnes by a rainforest. Dry matter production remains high throughout the 25-year economic life cycle of the oil palm forest [56,57]. What's more, plants normally adsorb CO_2 and returns oxygen (O_2) to the atmosphere but oil palm does more. Table 7 displays the comparisons of oil palm versus soybean in CO_2 sequestering. It proves that oil palm could absorb and return more CO_2 and O_2 comparatively to soybean for the same planted area.

7. Economic land use and social benefit

Oil palm is one of the world's most efficient bearing crops in terms of land utilization, efficiency and productivity. A single ha produces up to 10 times more oil than other oilseeds. Oil palm yields an average of 3.68 tonnes of oil/ha/year (projected to rise to 6 tonnes within the next decade) compared to soybean, sunflower seed, and rapeseed (Table 8). All this comes from a mere 1.84% of the 218 million ha under global oilseeds cultivation [4]. This is done without farming subsidies as in Europe and the US. Income from a ha of oil palm, based on 2005 data, equals about RM 7350/year, compared to RM 6432 for agricultural crops in the UK–of which RM 1837 is from a EU subsidy [55].

Sustainable oil palm cultivation hosts a win-win situation. Whereby, a surge of oil palm plantations from the 1980s corresponding with higher standard of living through direct and indirect employment. This energy crop provides direct and indirect employment to 860,000 people excluding other multiplying effects and spin-offs activities [58]. Malaysian plantation management is highly developed and government has set up the Federal Land Development Authority (FELDA) [2] to reduced rural poverty through planting of economic crops such as oil palm. The exports of reasonable, healthy, nourishing and high-

Table 7
Performance of oil palm and soybean in CO_2 sequestering [55]

Oil crop	O_2 released (MnT)	CO_2 absorbed (MnT)	Average O_2 released (t/ha)	Average CO_2 absorbed (t/ha)
Oil palm	195.1	268.4	21.3	29.3
Soybean	236.9	325.7	2.56	3.52

Table 8
Oil palm versus other major oil crops [2]

Crop	Average oil yield (t/ha/year)
Oil palm	3.68
Rapeseed	0.59
Sunflower	0.42
Soybean	0.36

yielding Malaysian palm oil now feed some 1.3 billion people in 150 countries [58]. Oil palm is indeed a 'life' promoting energy.

8. Future R&D of oil palm utilization in Malaysia

As in all industries, research and development (R&D) is critical, particularly a nation like Malaysia being a big agricultural country, where oil palm is available in large quantities across the country. There is a need to generate information, increase production and processing efficiency and expand uses of oil palm through R&D. The main challenge now is how to maximize the utilization of oil palm to develop and manage the adequate, affordable and consistent energy in a sustainable manner for fuel's social and economic development and environmental protection. Based on the current technology and application, some aspects of research and development in Malaysia presently are as follows.

8.1. Establishment of research institutes

The palm oil industry has been able to do this through the establishment of the Palm Oil Research Institute of Malaysia (PORIM). The Governing Board of PORIM, which includes representatives from the industry and the government, is advised on the research programs of the institute by a Program Advisory Committee, the members of which are experts in their own fields appointed by the Board. Various links, such as the PORIM-Industry Forum and PORIM-Industry Committees have been established to ensure that R&D in PORIM is in line with industry needs and that research findings are disseminated to the industry and offered for commercialization [12]. Currently this institute has been taken over by MPOB.

8.2. Adequate legislation and implementation of research activities

It is possible for the government to ensure proper and sustainable development of an industry through adequate legislation and implementation of research activities, which can be financed through imposition of an industrial cess. Members of the industry themselves have a say in the management of the funds collected, which will ultimately be used for their benefit through R&D and market development activities. In this case Malaysia has established Palm Oil Registration and Licensing Authority (PORLA) to handle licensing and enforcement [12].

At present for oil palm, two statutory bodies had been established by law: the ORIM to handle R&D and the PORLA to handle licensing and enforcement. The government found it more synergistic to merge these two organizations into a single body called the MPOB, which is better able to serve industry interests [12].

8.3. National policies

Malaysian national policies such as the Ninth Malaysian Plan (Rancangan Malaysia Ke-9)(RMK9) have stressed the development and utilization of renewable energy in the Plan period [59]. Efforts to promote the development of biofuel using palm oil as a renewable source of energy will be undertaken during the Plan period in line with the

initiative to make the country a world leader and hub for palm oil. Designated pump stations, mainly in the Klang Valley, to supply diesel blended with 5.0% palm olein are expected to commence operation in 2006. For the initial phase, the blended diesel will be utilized by vehicles of selected Government agencies. Regulations for the blending of petroleum diesel and palm olein will be formulated. Efforts will also be undertaken to promote the export of palm-based diesel [59]. Furthermore RMK-9 has stressed the strengthening of agricultural and the agro-based industries. During the Ninth Plan period, the agriculture sector will be revitalized to become the third engine of growth in Malaysia. Hence oil palm cultivation and production will be exclusively important to successfully implement RMK-9.

9. Conclusion

The potential utilization of oil palm in various industrial fields in Malaysia has been discussed. Oil palm not only can be used as source of edible oil but also it can be enhanced into excellent renewable energy. Oil palm is one of the most productive bio-diesel crop. Moreover, its waste streams can be used to produce vast amounts of bio-gas and other values added products. This facts proves that oil palm is an energy crop that yields the highest energy balance of all energy crops ('Energy Returned on Energy Invested' is between 12 and 14) [44], leaving all other competitors far behind. With this encouraging achievement, oil palm industries will circuitously intensify the economic and revenue growth of Malaysia. In near future CPO, bio-diesel made from oil palm and oil palm by-products made from Malaysia could be one of the major contributors of renewable energy in the world, at the same time.

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